CAVIAR: Climate Variability of the Baltic Sea area (ICES CM 2008/Q:17)

K. Getzlaff[1] [kgetzlaff@ifm-geomar.de], R. Voss[2], H.-H. Hinrichsen[3], A. Lehmann[1], F. Köster[4], and J.Harlaß[1]

[1]Department of Ocean Circulation and Climate Dynamics, IFM-GEOMAR, Kiel, Germany
[2]Department of Economics, University of Kiel, Germany
[3]Department of Marine Ecology, IFM-GEOMAR, Kiel, Germany
[4]National Institute of Aquatic Resources, Technical University of Denmark, Kgs. Lyngby, Denmark

Background: The concept of anthropogenic global climate change has been established in recent years (*IPCC, 2007;* Fig.1) but little is established on the detection of systematic changes on regional scales. The Baltic Sea area (BSA; Fig.2) is directly linked to influences of the global climate and as a consequence to global climate change. Additionally large seasonal and inter-annual variation exist in the BSA with complex causes resulting from geographical location, land-sea contrast and variable topography. This implies impacts on the ecosystem while the affect on species composition, distribution and interaction is only partly understood at present time. Consequently the major question is how the BSA may respond on future changes, firstly in terms of changes in the dynamical parameters but secondly and more important in terms of biological processes such as secondary and tertiary production.

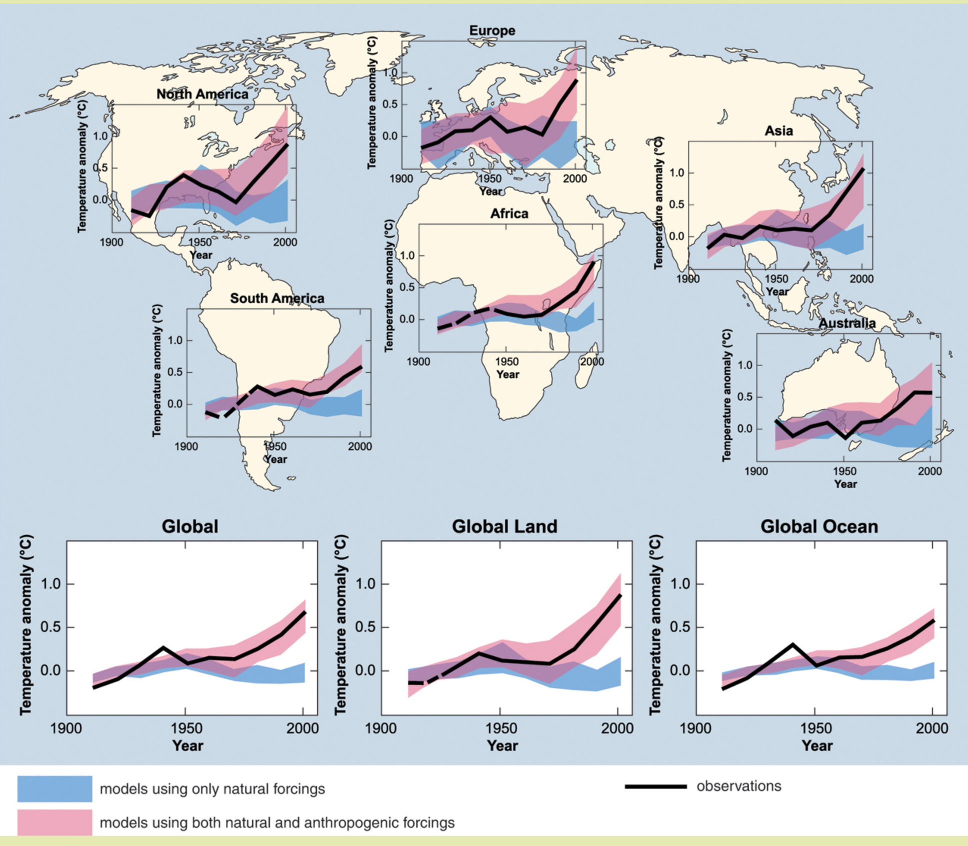

Fig.1: Global and continental temperature change. Black lines represent observations, pink shaded areas IPCC climate model results with anthropogenic forcing, blue shaded areas climate model results without anthropogenic forcing (*IPCC 2007, AR4 Synthesis Report Fig.SPM4*).

Trends/Indicators:

- **Warming trends in surface temperatures (Fig.3)**
- **Decrease of sea ice coverage and length of ice season**
- **Change in extreme events**

Goals of the newly launched project CAVIAR:

- Set up high-resolution numerical model (HRBSIOM) of the Baltic Sea area with updated forcing fields and refined topography
- Generate hindcast data set of hydrographic fields for the period 1970-2008 with focus on water mass exchange, sea ice evolution and changes in the ocean condition relevant to the spatial distribution of central Baltic fish and zooplankton populations
- Conduct set of runs with HRBSIOM using downscaled regional atmospheric forcing data from different climate scenario (A1B & B1) utilised for coupled bio-physical modelling to investigate the potential impact of future climate change

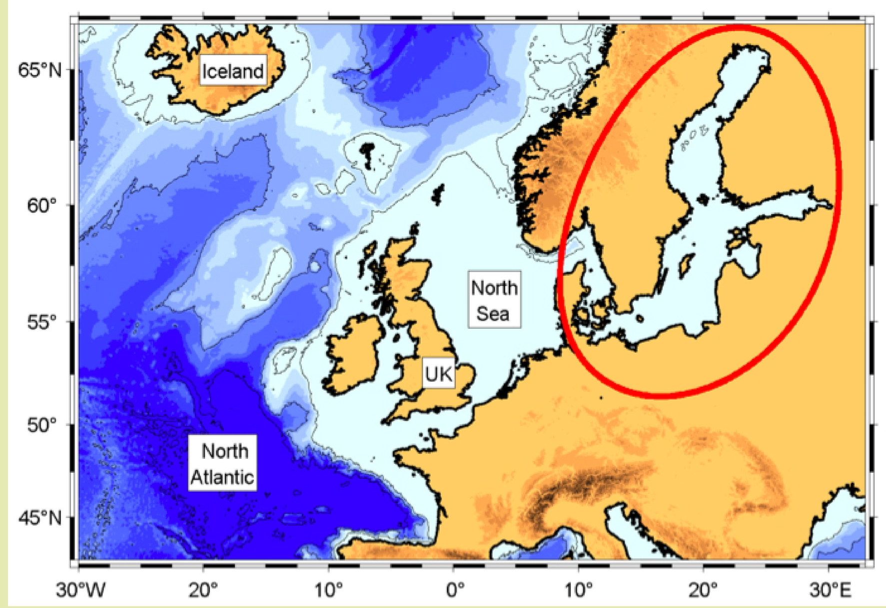

Fig.2: Location of the Baltic Sea area (red ellipsoid) embedded in a map of Northern Europe with parts of the North Atlantic Ocean.

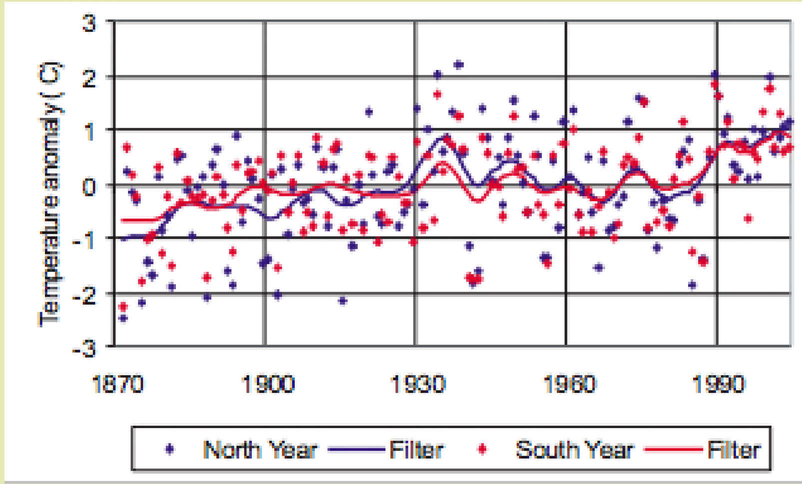

Fig.3: Annual mean 2-m air temperature anomalies (dots) for the Baltic Sea basin, based solely on land stations. Blue relates to north of 60°N, red to south of 60°N. Smoothed curves highlight variability on time scales longer than 10 years (*BACC 2008*).

Model: A high-resolution numerical coupled sea ice-ocean model of the Baltic Sea (HRBSIOM) will be set up based on BSIOM (*Lehmann, 1995*) with key features:

- Eddy-resolving (1nm x 1nm) due to better resolving the first baroclinic Rossby radius which varies strongly in the BSA (*Fennel et al., 1991*).
- Improved modeling of mixing and upwelling processes as well as inflow and outflow events of saline deep waters and fresh surface waters respectively.
- Updated atmospheric forcing for 1970-2008; likewise updated data set of hydrographic observations for evaluation and assimilation/re-initialisation

In addition to the high-resolution hindcast reference data set from 1970-2008 a set of runs will be conducted using regional atmospheric forcing for the Baltic Sea area from different climate scenarios (A1B & B1; Fig.4). These data sets will be utilised for bio-physical modelling to investigate and compare the potential effect of future climate change.

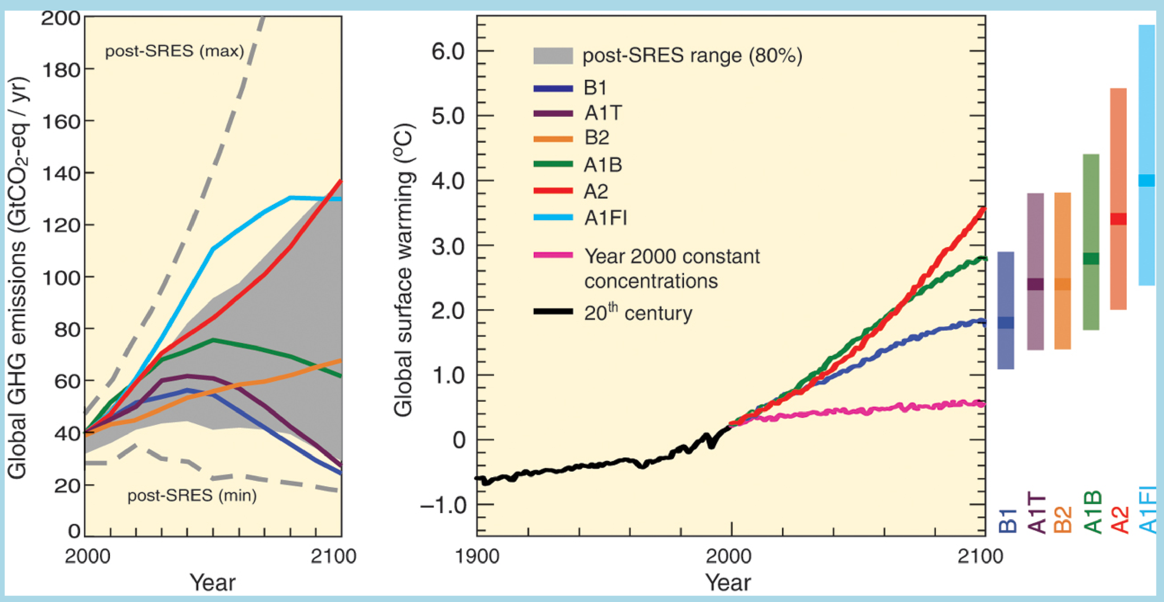

Fig.4: Left: Global GHG emissions in absence of climate policies in 6 SRES scenarios (coloured) with 80% range of recent scenarios published (gray). **Right:** Global averages of surface warming scenarios, with temperatures relative to 1980-1999 (*IPCC 2007, AR4 Synthesis Report Fig.SPM5*).

Biological application: From numerical model output it is possible to evaluate relationships between habitat utilisation and physical conditions of the environment.

- Relationship between recruitment variability of Baltic fish populations and abiotic environmental conditions (e.g. temperature, wind-field and transport patterns) affecting larval and juvenile stages (*Baumann, 2006*; Fig.5)
- Possible causes for the distribution or growth/reduction in population of invasive species in recent years such as the ctenophore ("comb jelly") Mnemiopsis leidyi (*Lehmann, 2008*; Fig.6).

The 4-dimensional data sets of realistic climate scenarios and reference runs could forecast variability of Baltic Sea zooplankton and fish population dynamics and e. g. could provide useful information for setting up Marina Protected Areas.

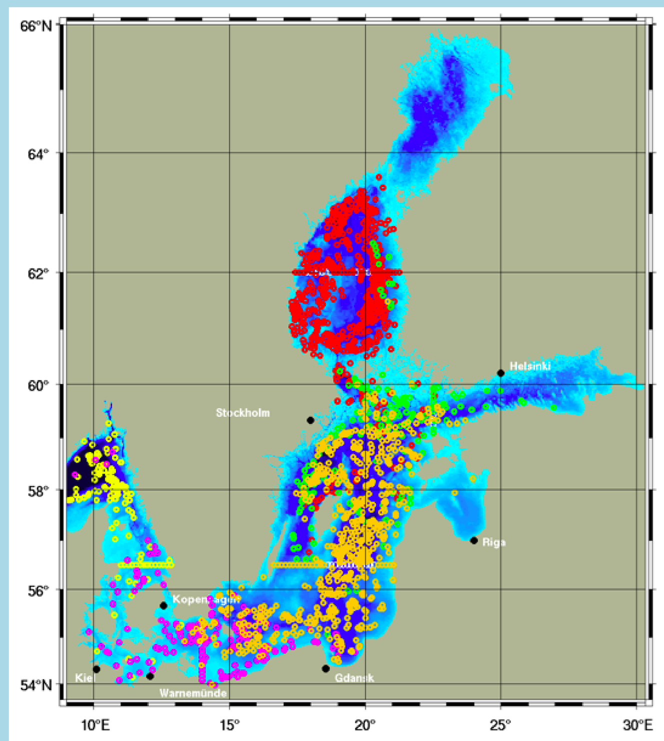

Fig.6: Start positions (white circles) of drifters released in January 2005 and end positions (colored circles; colours denote subbasins of origin) in December 2006.

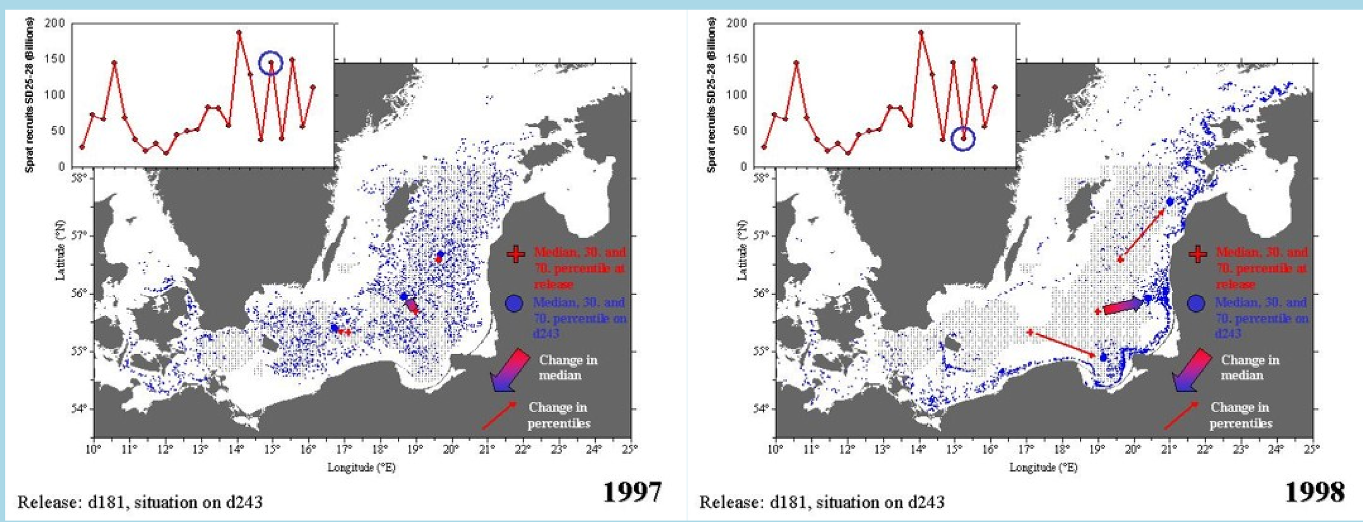

Fig.5: Distribution of 2671 Lagrangian particles (blue dots) released within areas of Baltic Sea sprat spawning effort and tracked for 62 days in 1997 (left) and 1998 (right). Shaded area indicates particle seeding pattern.

Analysis of meteorological forcing fields: We use the SMHI meteorological data base from 1970-2008 covering the whole Baltic Sea area. The analysis of meteorological forcing fields at Kiel, lighthouse (54°30'N, 10°16.5'E) confirms general warming trend seen in the BSA not only in near surface air temperature but also in changes of wind direction.

- The 2-m air temperature anomalies analysed with respect to the seasonal and annual mean (Fig.7), confirme positive trend of about 0.38°C/decade for winter season (DJF) as reported by *Lehmann et al., 2008*.
- Number of strong winters reduced to 6 events (less than 30%) in the 21 year period after 1985 (Fig.7), suggesting the begin of a different mode in the regional climate system.
- Increased frequency of westerly/south-westerly winds in winter time (DJF) for the later period, as a result mild humide air is advected leading to warmer temperatures and higher precipitation in some areas (Fig.8 left).
- Decreased frequency of south-westerly winds in autumn (SON) with additional increase in the occurrence of easterly winds leading to an advection of warm and dry air (Fig.8 right).
- Strong correlation of $R=0.73$ on the 95% confidence level between the NAO and Baltic Sea Index (BSI, *Lehmann et al., 2002*) with winter indices showing largest impact on changes in the characteristics of the atmospheric fields (Fig.9).

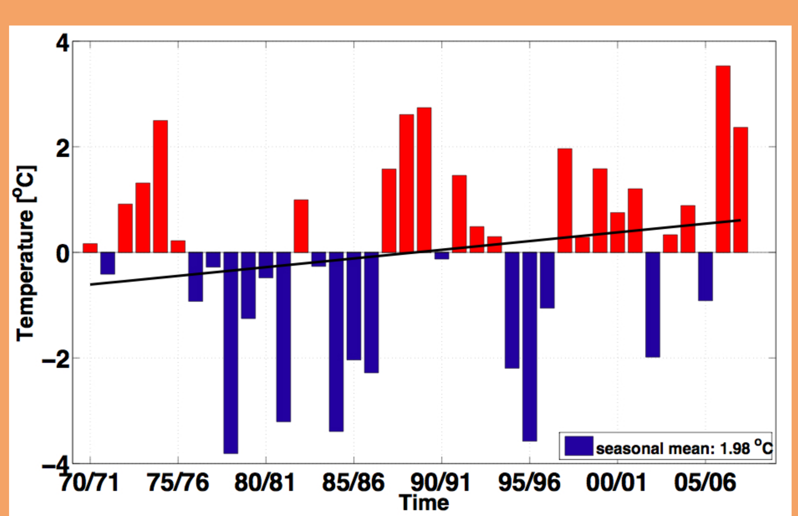

Fig.7: Near surface air temperature anomalies from SMHI data base at Kiel lighthouse with respect to the seasonal winter mean (DJF=1.98°C) for the period 1970 to 2008.

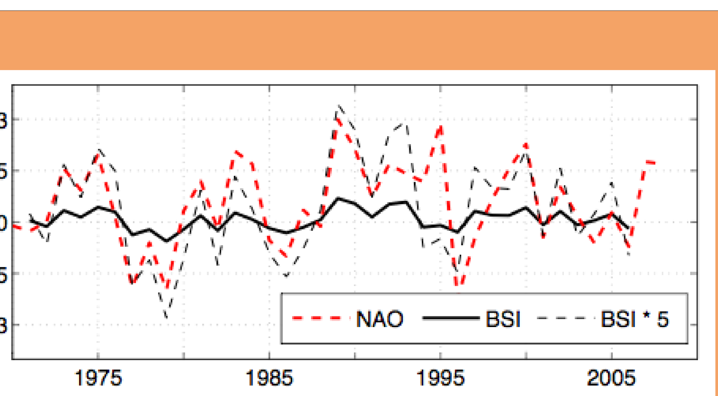

Fig.9: Time series of winter season of NAO index and BSI (Baltic Sea Index by *Lehmann et al., 2002*) for the period 1970 to 2008. For better comparison the BSI is additionally plotted with a multiplicative factor 5 (dashed thin black line). Correlation is given with *R=0.73* on the 95% confidence level.

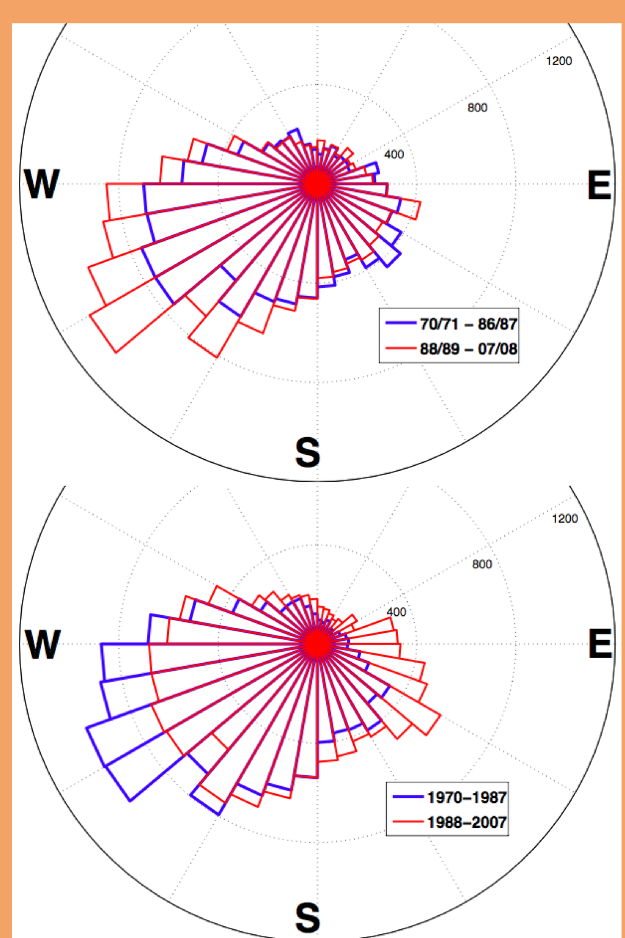

Fig.8: Frequency distribution of wind directions of two periods 1970-1987 (blue) and 1988-2007 (red) at the position Kiel, lighthouse estimated from the SMHI meteorological data base. Shown are for winter seasonal mean for winter (DJF; top) and autumn (SON; bottom).

Analysis of observational hydrographic field: Consistent to results of near surface air temperatures are the results from the analysis of water temperature profiles from the ICES data base from 1969 to 2005 (*Hinrichsen et al., 2007; Lehmann and Hinrichsen, 2007;* Fig.10).

- Large seasonal and inter-annual variability exist at the surface with a trend of 0.45°C/decade between 1969-2005 while for the whole water body the warming is only 0.09°C/decade.
- Separately looking at the period 1985-2005, the situation is much more distinct with a warming of 0.52°C/decade.

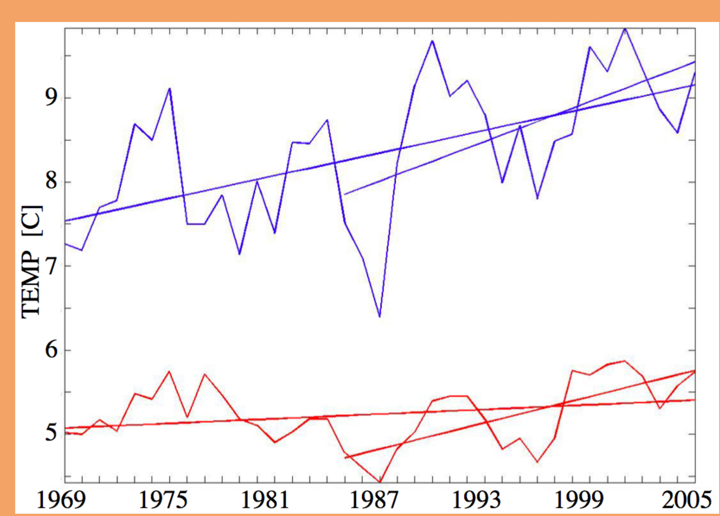

Fig.10: Annual mean temperature for the eastern Gotland Basin shown are surface temperature and linear trends for the period 1969-2005 and 1985-2005 (blue lines); vertical mean temperatures and linear trends for the period 1969-2005 and 1985-2005 (red lines).

References:

- BACC Author Team. 2008. Springer
- Baumann, H. et al. 2006: *Can. J. Fish. Aquat. Sci.* **63**
- Fennel, W., Seifert, T., Kayser, B. 1991: *Cont. Shelf Res.* **11**
- Hinrichsen et al. 2007: *Oceanologia* **49**
- IPCC (2007), Fourth Assessment Report. (www.ipcc.ch/ipccreports/ar4-syr.htm)
- Lehmann, A. 1995: *Tellus* **47A**
- Lehmann, A. and Hinrichsen, H.-H. 2007: *BALTEX Newsletter* **10**
- Lehmann et al. 2008: *BALTEX Newsletter* **11**